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| 2. | Patent application number *(The Patent Office will fill in this part)* | 20 SEP 1999 **9922140.0** |
| 3. | Full name, address and postcode of the or of each applicant *(underline all surnames)* | TIEDEMANNS-JOH. H. ANDRESEN ANS<br>TRADING AS TITECH-AUTOSORT<br>JOH. H. ANDRESENS VEI 5<br>N-0601 OSLO<br>NORWAY |
| | Patents ADP number *(if you know it)* | 662139 5002 |
| | If the applicant is a corporate body, give the country/state of its incorporation | NORWAY |
| 4. | Title of the invention | INSPECTION OF MATTER |
| 5. | Name of your agent *(if you have one)* | ANTHONY BURROWS |
| | "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)* | BUSINESS CENTRE WEST<br>AVENUE ONE, BUSINESS PARK<br>LETCHWORTH GARDEN CITY<br>HERTFORDSHIRE<br>SG6 2HB |
| | Patents ADP number *(if you know it)* | 31666001 |

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12. Name and daytime telephone number of person to contact in the United Kingdom

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# INSPECTION OF MATTER

This invention relates to automatically inspecting matter, for example automatic inspection and sorting of discrete objects of differing compositions, e.g. waste objects, or automatic inspection of sheet material, which may be in the form of a strip, for surface layer composition, e.g. surface layer thickness.

With the recent focus on collection and recycling of waste, the cost effectiveness of waste sorting has become an essential economic parameter.

In the "Dual System" in Germany all recyclable "non-biological" packaging waste excluding glass containers and newsprint is collected and sorted in more than 300 sorting plants.

Objects can be sorted on the basis of:-

Size
Density/weight
Metal content (using eddy current effect)
Ferrous metal content (using magnetic separation)

but most objects such as plastics bottles and beverage cartons are still today sorted out manually to a considerable extent. Some beverage cartons contain an aluminium barrier and by eddy current induction they can be expelled from the waste stream. Generally, beverage cartons in their simpler form present a composite object consisting of paperboard with polymer overcoats on both their inside and outside surfaces.

Several sorting systems exist today that can sort a number of different plastics bottles/objects from each other when they arrive sequentially (i.e. one-by-one). The detection is based on reflected infrared spectrum analysis. To separate the various polymers a quite elaborate variance analysis is performed and thus detection systems become expensive. The objects being fed sequentially pass beneath the infrared spectral detector whereby infrared is shone onto the objects and the relative intensities of selected wavelengths of the infrared radiation reflected are used to determine the particular plastics compound of

the plastics passing beneath the detection head. Downstream of the detection head are a number of air jets which blow the individual plastics objects into respective bins depending upon the plastics which constitutes the majority of the object.

A similar system is disclosed in US-A-5,134,291 in which, although the objects to be sorted can be made of any material, e.g. metals, paper, plastics or any combination thereof, it is critical that at least some of the objects be made predominantly from PET (polyethylene terephthalate) and PS (polystyrene) as well as predominantly from at least two of PVC (polyvinyl chloride), PE (polyethylene) and PP (polypropylene), for example objects including: an object made predominantly from PET, an object made predominantly from PS, an object made predominantly from PVC and an object made predominantly from PE. A source of NIR (Near Infra Red), preferably a tungsten lamp, radiates NIR onto a conveyor sequentially advancing the objects, which reflect the NIR into a detector in the form of a scanning grating NIR spectrometer or a diode array NIR spectrometer. The detector is connected to a digital computer connected to a series of solenoid valves controlling a row of air-actuated pushers arranged along the conveyor opposite a row of transverse conveyors. The diffuse reflectance of the irradiated objects in the NIR region is measured to identify the particular plastics of each object and the appropriate solenoid valve and thus pusher are operated to direct that object laterally from the conveyor onto the appropriate transverse conveyor. The computer can manipulate data in the form of discrete wavelength measurements and in the form of spectra. A measurement at one wavelength can be ratioed to a measurement at another wavelength. Preferably, however, the data is manipulated in the form of spectra and the spectra manipulated, by analogue signal processing and digital pattern recognition, to make the differences more apparent and the resulting identification more reliable.

DE-A-4312915 discloses the separation of plastics, particularly of plastics waste, into separate types, on the

basis of the fact that some types of plastics have characteristic IR spectra. In the IR spectroscopic procedure, the intensity of diffusely reflected radiation from each sample is measured on a discrete number of NIR wavelengths simultaneously and the intensities measured are compared. Measurements are taken on wavelengths at which the respective types of plastics produce the minimum intensities of reflected radiation. If, for example, three different plastics are to be separated, each sample is measured on three wavelengths simultaneously, whereby one type of plastics is identified in a first comparison of the intensity of the reflected radiation on the lowest wavelength with that of the second-lowest wavelength and the other two types of plastic are determined in a second comparison of the greater intensity on one wavelength in the first comparison with the intensity on the third wavelength. To measure the light on particular wavelengths, respective detectors can have narrow band pass filters for the respective requisite wavelengths, and respective constituent cables of a split optical fibre cable are allocated to the respective detectors, the cable entry lying in the beam path of a lens for detecting the light reflected from the sample. Alternatively, a light dispersing element, e.g. a prism or grid, is placed in the beam path after the lens and several detectors are arranged to detect the NIR of the requisite wavelengths. Sorting facilities are controlled by utilising the detection data obtained by the comparisons. As a further example, five differing plastics, namely PA (polyamide), PE, PS, PP and PETP, may be separated, utilising measurement points at five differing wavelengths between 1500nm. and 1800nm.

EP-A-557738 discloses an automatic sorting method with substance-specific separation of differing plastics components, particularly from domestic and industrial waste. In the method, light is radiated onto the plastics components, or the plastics components are heated to above room temperature, light emitted by the plastics components and/or light allowed through them (in an embodiment in which

light transmitted through the components and through a belt conveying them is measured) is received on selected IR wavelengths, and the material of the respective plastics components is identified from differences in intensity (contrast) between the light emitted and/or absorbed, measured on at least two differing wavelengths. The light emitted or allowed through is received by a camera which reproduces it on a detector through a lens. A one-dimensional line detector is usable, although a two-dimensional matrix detector or a one-element detector with a scanning facility can be employed. In order that the camera may receive the light on selected IR wavelengths, interference filters may be mounted either in front of the light source or in front of the lens or the detector. In an example in which the material of the plastics components is identified from the differences in intensity of emitted light at two differing wavelengths, the wavelengths are chosen to produce maximum contrast. This means that one wavelength is selected so that maximum intensity of the emitted light is obtained at a specified viewing angle, whereas the other wavelength is selected so that minimum intensity is obtained at that viewing angle. Changing of wavelengths may be achieved by mounting the filters on a rotating disc, with the frequency of rotation being synchronised with the imaging frequency of the detector. Alternatively, an electrically triggered, tunable, optical filter may be employed. The electrical signals generated by the detector are fed to an electronic signal processor, digitised, and subsequently evaluated by image processing software. It is ensured that the plastics components are at approximately the same temperature at the time of imaging, as differences in contrast can also be caused by temperature differences. The belt should consist of a material which guarantees constant contrast on individual wavelengths.

There is also previously known a system in which infrared spectral detection is performed from below the objects, with the objects passing sequentially over a hole up through which the IR is directed. Again, the infrared

reflected is used to sort the objects according to the various plastics within the respective objects.

US-A-5260576 and US-A-5339962 disclose a method and apparatus for distinguishing and separating material items having different levels of absorption of penetrating electromagnetic radiation by utilising a source of radiation for irradiating an irradiation zone extending transversely of a feed path over which the material items are fed or passed. The irradiation zone includes a plurality of transversely spaced radiation detectors for receiving the radiation beams from the radiation source, the detectors receiving the radiation substantially on a direct line from the source. The material items pass through the irradiation zone between the radiation source and the detectors and the detectors measure one or more of the transmitted beams in each item passing through the irradiation zone to produce processing signals which are analysed by signal analysers to produce signals for actuating a separator device in order to discharge the irradiated items toward different locations depending upon the level of radiation absorption in each of the items. The disclosure states that mixtures containing metals, plastics, textiles, paper and/or other such waste materials can be separated since penetrating electromagnetic radiation typically passes through the items of different materials to differing degrees, examples given being the separation of aluminium beverage cans from mixtures containing such cans and plastic containers and the separation of chlorinated plastics from a municipal solid waste mixture. The source of penetrating radiation may be an X-ray source, a microwave source, a radioactive substance which emits gamma rays, or a source of UV energy, IR energy or visible light. One example of material items which are disclosed as having been successfully separated are recyclable plastic containers, such as polyester containers and polyvinyl chloride (PVC) containers, which were separated using X-rays. WO-A-95/03139 discloses a similar system which is employed for automatically sorting post-consumer glass and plastics

containers by colour.

In an eddy current system for ejecting metal from a stream of waste, the discharge end roller of a belt conveyor normally contains a strong alternating magnetic field generated by permanent magnets contained within and distributed along the roller and counter-rotating relative to the sense of rotation of the roller. This field ejects metallic objects to varying degrees depending upon the amount and the conductivity of the metal of the object. Since metallic objects in which the metal content is small, for example post-consumer packaging cartons of a laminate consisting of polymer-coated paperboard and aluminium foil, are only weakly affected by the magnetic field, such cartons tend not to be separated-out by the eddy-current ejection system.

Another known system uses an electromagnetic field for eddy current detection through induction of eddy currents in the metal in metallic objects and the detection output is used to control an air jet ejection arrangement but this time the objects are caused to queue up one after another in single lines.

US-A-4996440 discloses a system for measuring one or a plurality of regions of an object to be able to determine one or a plurality of dimensions of the object. In one example, the system utilises a mirror arrangement for transmitting pulsed laser light so that the light impinges downwards upon the object and for receiving the upwardly reflected light. The system includes a laser, a rotating planar mirror and a concave frusto-conical mirror encircling the planar mirror, which serve for directing the light beam towards the object. The frusto-conical mirror, the planar mirror and a light receiver serve for receiving light beams which are reflected from the object. Electronic circuitry connected to the light receiver serves for calculating the travel time of the beam to and from the object, with a modulator causing the light beam to be modulated with a fixed frequency and the rotating planar mirror and the frusto-conical mirror causing the light beam to sweep across

the object at a defined angle/defined angles relative to a fixed plane of reference during the entire sweeping operation.

WO-A-96/06689 discloses a system for automatically inspecting matter for varying composition and comprising one or more detection stations through which one or more streams of matter are advanced and particular materials therein are detected through their diffusely reflected IR spectra, if any, and/or through their variation of an electromagnetic field by their metallic portions, if any. In one version, a multiplicity of detection points represented by lenses are distributed in a straight line across and below the stream as it passes over a transverse slot through a downwardly inclined plate at the downstream end of a conveyor belt, with a separate light source for each lens. Optical fibres transmit the IR from the respective lenses to a rotary scanner whence a diffuser shines the IR onto infrared filters ahead of IR detectors dedicated to respective wavelengths, to date output of which is utilized in controlling air jet nozzles which separate-out desired portions of the stream. In other versions, a row of light sources distributed across the overall width of one or more belt conveyors may cause desired portions of the stream at detection points distributed in an arc across the stream to reflect light diffusely onto a part-toroidal mirror extending over that overall width, whence the light is reflected, by a rotating, polygonal mirror through optical filters dedicated to differing IR wavelengths, onto detectors the data output of which is utilised in controlling solenoid valves operating air jet nozzles which separate-out the desired portions. Alternatively or additionally, an oscillator and an antenna which extends over that overall width generate an electromagnetic field through the belt and sensing coils sense variations therein produced by metallic portions of the stream passing through the detection station and the detection data produced by the sensing coils is used to control the solenoid valves operating the nozzles to separate-out the metallic portions. In a further version, the

rotating, polygonal mirrors are retained and the part-toroidal mirror may be replaced by a mirror comprised of a series of facets or very small mirrors in a horizontal row transverse to the stream, which in this version is a laminate comprised of paperboard onto which a polymer has been extruded. The detection points are arranged in a straight row across the laminate.

According to a first aspect of the present invention, there is provided a method of automatically inspecting matter, comprising emitting a detection medium, which comprises electromagnetic radiation, to be active at said matter, said medium being varied by variations in said matter receiving the varied medium either directly, or via a folding mirror, from said matter at a rotary polygonal mirror, reflecting the varied medium from the rotary polygonal mirror to detecting means, detecting at said detecting means a plurality of wavelengths of said varied medium substantially simultaneously, and generating detection data from said detecting means in respect of said plurality of wavelengths substantially simultaneously and in dependence upon the variations in said medium.

According to a second aspect of the present invention, there is provided apparatus for automatically inspecting matter, comprising emitting means serving to emit a detection medium, which comprises electromagnetic radiation, to be active at said matter, a rotary polygonal mirror arranged to receive directly, or via a folding mirror, from said matter detection medium varied by variations in said matter, and detecting means serving to receive the varied medium by reflection from the rotary polygonal mirror, to detect a plurality of wavelengths of said varied medium substantially simultaneously, and to generate detection data in respect of said plurality of wavelengths substantially simultaneously and in dependence upon the variations in said medium, and data-obtaining means connected to said detecting means and serving to obtain said detection data therefrom.

According to a third aspect of the present invention, there is provided a method of automatically inspecting

matter, comprising emitting a detection medium, which comprises electromagnetic radiation, to be active at said matter, said medium being varied by variations in said matter, receiving the varied medium from said matter at a rotary polygonal mirror, said varied medium converging continuously throughout its path from said matter to said polygonal mirror, reflecting the varied medium from the mirror to detecting means, detecting at said detecting means a plurality of wavelengths of said varied medium substantially simultaneously, and generating detection data from said detecting means in respect of said plurality of wavelengths substantially simultaneously and in dependence upon the variations in said medium.

According to a fourth aspect of the present invention, there is provided apparatus for automatically inspecting matter, comprising emitting means serving to emit a detection medium, which comprises electromagnetic radiation, to be active at said matter, a rotary polygonal mirror arranged to receive from said matter detection medium which has been varied by variations in said matter and which has converged continuously throughout its path from said matter to said receiving means, and detecting means serving to receive the varied medium by reflection from the mirror, to detect a plurality of wavelengths of said varied medium substantially simultaneously, and to generate detection data in respect of said plurality of wavelengths substantially simultaneously and in dependence upon the variations in said medium, and data-obtaining means connected to said detecting means and serving to obtain said detection data therefrom.

Owing to these four aspects of the present invention, it is possible to simplify and thus reduce the cost of the apparatus compared with a known apparatus in which the varied medium is received at the rotary polygonal mirror by way of a mirror of a character which is complicated and expensive to produce.

Preferably, the matter is advanced through a detection station at which the detection medium is active.

The reflective faces of the rotary polygonal mirror are

at least two in number and may be either planar or curved and either substantially parallel or inclined to the axis of rotation of the mirror, i.e. the mirror may be cylindrical or pyramidal.

A particular advantage of the feature that the varied medium converges continuously throughout its path from said matter to said receiving means is that the matter width covered by the receiving means (in the form of the rotary polygonal mirror) can be changed by changing the spacing between the matter and the receiving means, whereby a plurality of arrangements each comprising such receiving means, such detecting means and such data-obtaining means can be disposed side-by-side, particularly in the form of modules, transversely of the matter so that each arrangement inspects part of the width of the matter and the width parts inspected by the respective arrangements overlap each other to desired extents.

According to a fifth aspect of the present invention, there is provided a method of automatically inspecting matter, comprising causing said matter to advance in a feed direction through a detection station, emitting a detection medium, which comprises electromagnetic radiation, to be active at said matter at said detection station, said medium being varied by variations in said matter at said detection station, receiving the varied medium at a rotary polygonal mirror having its axis of rotation at substantially the axis of its polygon and extending in said feed direction, reflecting the varied medium from the mirror to detecting means, detecting at said detecting means a plurality of wavelengths of said varied medium substantially simultaneously, and generating detection data from said detecting means in respect of said plurality of wavelengths substantially simultaneously and in dependence upon the variations in said medium.

According to a sixth aspect of the present invention, there is provided apparatus for automatically inspecting matter, comprising a detection station through which said matter advances in a feed direction, emitting means serving

to emit a detection medium, which comprises electromagnetic radiation, to be active at said matter at said station, a rotary polygonal mirror at said station arranged to receive detection medium varied by variations in said matter at said station, and detecting means serving to receive the varied medium by reflection from the mirror, to detect a plurality of wavelengths of said varied medium substantially simultaneously, and to generate detection data in respect of said plurality of wavelengths substantially simultaneously and in dependence upon the variations in said medium, and data-obtaining means connected to said detecting means and serving to obtain said detection data therefrom, said mirror having its axis of rotation at substantially the axis of its polygon and extending in said feed direction.

Owing to these two aspects of the invention, it is possible to simplify and thus reduce the cost of the apparatus compared with a known apparatus in which the varied medium is transmitted to the mirror by way of a part-toroidal mirror or a multi-facetted or similar mirror. Again, the polygonal mirror may be cylindrical or pyramidal.

According to a seventh aspect of the present invention, there is provided a method of automatically inspecting an object, comprising emitting a detection medium to be active at surfaces of said object orientated differently from each other, said medium being varied in its intensity in dependence upon the respective orientations of said surfaces receiving the varied medium at receiving means, generating detection data in dependence upon the variations in the intensity of said medium received at said receiving means, and using said detection data to obtain an indication of a dimension of said object.

According to an eighth aspect of the present invention, there is provided apparatus for automatically inspecting an object, comprising emitting means serving to emit a detection medium to be active at surfaces of said object orientated differently from each other, receiving means arranged to receive detection medium varied in its intensity in dependence upon the respective orientations of said

surfaces, and detecting means serving to generate detection data in dependence upon the variations in the intensity of said medium received at said receiving means, and data-obtaining means connected to said detecting means and serving to obtain said detection data therefrom and to use said detection data to obtain an indication of a dimension of said object.

Owing to these two aspects of the present invention, it is possible to identify an uncrushed container, for example, since irradiation from one general direction will produce variations in the intensity of the irradiation of the surfaces in dependence upon their orientation and from the consequential variations in the reflected medium the volume of the container can be determined. Furthermore, if, say, the wavelength of the medium is varied by variations in the composition of the containers, then also the composition of the containers can be determined.

Preferably, the object is advanced through a detection station at which the detection medium is active.

According to a ninth aspect of the present invention, there is provided a method of automatically inspecting matter, comprising emitting a detection medium to be active at said matter, said medium being varied by variations in said matter, receiving the varied medium at first and second receivers which receive the varied medium from a common zone of said matter in respective different directions inclined to each other, generating first and second series of detection data in dependence upon the variations in said medium received at said first and second receivers, and using said first and second series of detection data to obtain an indication of the height of said common zone.

According to a tenth aspect of the present invention, there is provided apparatus for automatically inspecting matter, comprising emitting means serving to emit a detection medium to be active at said matter, first and second receivers arranged to receive, in respective different directions inclined to each other and from a common zone of

said matter, detection medium varied by variations in said matter, and first and second detecting means serving to generate first and second series of detection data in dependence upon the variations in said medium received at said first and second receivers, and data-obtaining means connected to said first and second detecting means and serving to obtain said first and second series of detection data therefrom and to use said first and second series of detection data to obtain an indication of the height of said common zone.

Owing to these two aspects of the present invention, it is possible to identify uncrushed containers, for example, in the matter, since, if, say, the intensity of the medium is varied by variations in the orientation of the matter at respective detection zones at the matter, then the volume of the containers can be determined by the comparison of the first and second series of data. Furthermore, if, say, the wavelength of the medium is varied by variations in the composition of the matter at those detection zones, then also the composition of the containers can be determined.

Preferably, the matter is advanced through a detection station at which the detection medium is active.

According to an eleventh aspect of the present invention, there is provided a method of automatically inspecting matter, comprising causing said matter to fall freely at a detection level at a detection station more vertically than horizontally, emitting a detection medium, which comprises electromagnetic radiation, to be active at the freely falling matter at said detection level, said medium being varied by variations in the freely falling matter at said detection level, receiving the varied medium at detecting means, detecting at said detecting means a plurality of wavelengths of said varied medium substantially simultaneously and generating detection data from said detecting means in respect of said plurality of wavelengths substantially simultaneously and in dependence upon the variations in said medium.

According to a twelfth aspect of the present invention,

there is provided apparatus for automatically inspecting matter, comprising a detection station at a detection level of which said matter falls freely more vertically than horizontally, emitting means serving to emit a detection medium, which comprises electromagnetic radiation, to be active at the freely falling matter at said level, receiving means at said station arranged to receive detection medium varied by variations in said freely falling matter at said level, and detecting means serving to detect a plurality of wavelengths of said varied medium substantially simultaneously and to generate detection data in respect of said plurality of wavelengths substantially simultaneously and in dependence upon the variations in said medium, and data-obtaining means connected to said detecting means and serving to obtain said detection data therefrom.

Owing to these two aspects of the present invention, wherein the matter advances at the detection station in a freely falling condition, it is possible to carry out the detection without needing to take into account the presence of some conveying means and also possible to carry out reflection-reliant detection at a substantially constant spacing between the advancing matter and the receiving means. Moreover, the feature whereby the matter falls more vertically than horizontally (preferably either vertically or almost vertically) at the detection level has the advantage that the apparatus can be compact horizontally, which is a particularly desired feature in a recycling plant.

By means of a suitable deflector above the level at which the detection medium is to be active, the matter can be caused to fall freely in a curved distribution around a vertical axis, most preferably at a substantially constant radius from that axis.

According to a thirteenth aspect of the present invention, there is provided a method of automatically inspecting matter, comprising emitting a beam of detection medium to scan said matter, said medium being varied by variations in said matter, receiving the varied medium at detecting means, and generating detection data from said

detecting means in dependence upon the variations in said medium.

According to a fourteenth aspect of the present invention, there is provided apparatus for automatically inspecting matter, comprising emitting means serving to emit a beam of detection medium and to cause said beam to scan said matter, receiving means arranged to receive a return beam of detection medium varied by variations in said matter at said station, and detecting means serving to generate detection data in dependence upon the variations in said medium, and data-obtaining means connected to said detecting means and serving to obtain said detection data therefrom.

Owing to these two aspects of the invention, it is possible to save energy in production of the detection medium, without losing intensity level of the varied medium received at the receiving means. If the sensitivity of the detecting means is liable to be saturated by the intensity of the direct return beam, then the detecting means is offset relative to the direct return path. The emitted beam may be continuous or pulsed. It is advantageous to emit two or more scanning beams simultaneously and to direct them at substantially a common region of the station, in order to give widespread exposure to the medium of surface portions of the matter at the region.

Preferably, the matter is advanced through a detection station at which the detection medium is active.

According to a fifteenth aspect of the present invention, there is provided a method of automatically inspecting matter for varying composition, comprising advancing a stream of said matter comprised of individual objects, emitting a detection medium to be active at a multiplicity of individual detection zones distributed across substantially the width of said stream at a transverse section of said stream, said medium being varied by variations in the composition of said matter at said transverse section, receiving the varied medium at receiving means, generating detection data in dependence upon the variations in said medium, utilizing a

camera to detect positions of said objects, and generating further data in dependence upon said positions.

According to a sixteenth aspect of the present invention, there is provided apparatus for automatically inspecting matter for varying composition, comprising detection station means through which a stream of said matter comprised of individual objects advances, emitting means serving to emit a detection medium to be active at a multiplicity of individual detection zones distributed across substantially the width of said stream at a transverse section of said stream at said station means, receiving means serving to receive detection medium varied by variations in the composition of said matter at said section, detecting means serving to generate a first series of detection data in dependence upon the variations in said medium, a camera at said station means and serving to detect positions of said objects and serving to generate a second series of detection data in dependence upon said positions, and data-obtaining means connected to said detecting means and to said camera and serving to obtain the first and second series of detection data therefrom.

Owing to these aspects of the present invention, it is possible simply and inexpensively to sort objects according to their size and/or their composition, as desired, and/or to eject at consecutive stages respective fractions of the stream which differ from each other in respect of their characteristics, e.g. their compositions or their colours.

According to a seventeenth aspect of the present invention, there is provided a method of automatically inspecting matter, comprising emitting a detection medium to be active at said matter, said medium being varied by variations in said matter, receiving the varied medium at receiving means, from, in turn, the multiples of a group of multiples of detection zones at said matter, with the varied medium from all of the detection zones in each multiple being received substantially simultaneously, and generating detection data for each detection zone in dependence upon the variations in said medium at the detection zone.

According to an eighteenth aspect of the present invention, there is provided apparatus for automatically inspecting matter, comprising emitting means serving to emit a detection medium to be active at said matter, receiving means serving to receive detection medium varied by variations in said matter from, in turn, the multiples of a group of multiples of detection zones at said matter, with the varied medium from all of the detection zones in each multiple being received substantially simultaneously, and detecting means serving to generate detection data in dependence upon the variations in said medium at each detection zone, and data-obtaining means connected to said detecting means and serving to obtain said detection data therefrom.

Owing to these two aspects of the invention, it is possible to increase the resolution of detection by a factor of the multiple of detection zones in each group and thereby to increase the resolution for the same speed of detection. Thus, relatively smaller objects can be more accurately identified as to their position (and composition if desired), so that it is possible to provide a system particularly suited to sorting of granulates.

According to a nineteenth aspect of the present invention, there is provided a method of automatically inspecting matter, comprising emitting a detection medium to be active at said matter, wherein said medium is varied by variations in said matter, receiving the varied medium from said matter at respective first and second receiving means of respective first and second inspection arrangements, reflecting the varied medium from the first and second receiving means to respective first and second detecting means of said respective first and second inspection arrangements, detecting said varied medium at said first and second detecting means, and generating detection data from said first and second detecting means in dependence upon the variations in said medium.

According to a twentieth aspect of the present invention, there is provided apparatus for automatically

inspecting a stream of matt r, comprising emitting means serving to emit a detection medium to be active at said matter, first and second receiving means of respective first and second inspection arrangements arranged to receive from said matter detection medium varied by variations in said matter, and first and second detecting means of said respective first and second inspection arrangements serving to receive the varied medium by reflection from the receiving means, and to generate detection data in dependence upon the variations in said medium, and data-obtaining means connected to said first and second detecting means and serving to obtain said detection data therefrom.

Owing to these two aspects of the present invention, it is possible to increase the matter width capable of being inspected and/or to improve the resolution of the inspection of the same matter width, in that the inspection arrangements may inspect respective parts of the width of the matter or may each inspect substantially the whole width of the matter. Advantageously, the inspection path of each arrangement is substantially rectilinear and substantially perpendicularly transverse to the matter and, very preferably, the inspection paths are substantially co-incident where they overlap or are directly end-to-end if they do not overlap. It is especially desirable that the inspection arrangements should either commence respective widthwise scans from a common location or terminate respective widthwise scans at a common location. The inspection arrangements may take the form of respective modules arranged side-by-side with each other.

According to a twenty-first aspect of the present invention, there is provided a method of automatically inspecting matter, comprising emitting a detection medium, which comprises radiation, to irradiate a path over said matter, inspecting the irradiated path at an oblique angle to said matter, and ascertaining from that inspection the general profile of that path.

According to a twenty-second aspect of the present invention, there is provided apparatus for automatically inspecting matter, comprising emitting means serving to

emit a detection medium, which comprises radiation, to irradiate a path over said matter, inspection means arranged to inspect the irradiated path at an oblique angle to said matter, and ascertaining means arranged to ascertain from that inspection the general profile of that path.

Owing to these two aspects of the present invention, it is possible in a simple manner to ascertain the general profile of the matter, especially the general profiles of objects of which the matter is comprised.

The emitting means can emit either a fixed sheet of the radiation to irradiate the whole length of the path simultaneously or a scanning beam of the radiation to scan the path.

According to a twenty-third aspect of the present invention, there is provided a method of inspecting matter, comprising emitting from emitting means a detection medium, which comprises radiation, to be active at said matter, said medium being varied by variations in said matter, at least part of the emitted medium passing through said matter and the medium which has passed through said matter being received at detecting means, and preventing said detecting means from receiving the medium directly from the emitting means.

According to a twenty-fourth aspect of the present invention, there is provided apparatus for inspecting matter, comprising emitting means serving to emit a detection medium, which comprises radiation, to be active at said matter, detecting means arranged to receive, by passage of the medium through said matter, detection medium varied by variations in said matter, and shielding means arranged to prevent the detecting means from receiving the medium directly from the emitting means.

Owing to these aspects of the invention it is possible to prevent swamping of the detecting means by medium received directly from the emitting means, and thus for the receiving means to be relatively highly sensitive to variations in the medium.

According to a twenty-fifth aspect of the present invention, there is provided a method of inspecting relatively solid matter, comprising emitting a detection medium, which comprises radiation, to be active at said matter at a detection section, said medium being varied by variations in said matter, receiving the varied medium at detecting means, and calibrating said detecting means by continually comparing with each other intensities of said radiation received by said detecting means in circumstances where none of said matter is present at a detection zone of said detection section.

According to a twenty-sixth aspect of the present invention, there is provided apparatus for automatically inspecting matter, comprising a detection station, emitting means serving to emit a detection medium, which comprises electromagnetic radiation, to be active at said matter at a detection section of said station, detecting means arranged to receive detection medium varied by variations in said matter at said section, and calibrating means serving to calibrate said detecting means by continually comparing with each other intensities of said radiation received by said detecting means in circumstances where none of said matter is present at a detection zone of said detection section.

Owing to these aspects of the invention, it is possible to compensate for changes in the detection medium as emitted by the emitting means, for example owing to ageing of the emitting means or interference with the emitting means by extraneous material.

Preferably, the matter is advanced through a detection station at which the detection medium is active.

The present invention is applicable to a wide variety of systems of automatically inspecting matter.

By applying multiple sensors and/or a scanning arrangement, it becomes possible to introduce a large number of detection points.

The detection medium can be electromagnetic radiation, for example IR or visible light, to detect variations in constituency or colour, or an electromagnetic field to

detect metal portions of the stream, e.g. in sorting of materials. A wide variety of materials may be sorted from each other, but particularly plastics-surfaced objects sorted from other objects. For the present automatic sorting, the objects must be distributed in substantially a single layer.

For sorting of objects, the objects may be caused to fall freely. Alternatively, they may be advanced through the detection station on an endless conveyor belt. If the objects to be separated-out are plastics objects which are substantially transparent to the electromagnetic radiation, e.g. IR, then the conveying surface of the belt should be diffusely reflective of the electromagnetic radiation.

For a polymer, two or more detection wavelength bands in the NIR region of 1.5 microns to 1.85 microns can be employed. For a laminate comprised of polyethylene on paperboard, a first wavelength band centred on substantially 1.73 microns is employed, as well as a second wavelength band centred less than 0.1 microns from the first band, for example at about 1.66 microns.

The matter may comprise laminate comprised of a first layer and a second layer underneath said first layer and of a material having a spectrum of reflected substantially invisible electromagnetic radiation significantly different from that of the material of the first layer. As a result, the spectrum of substantially invisible electromagnetic radiation, particularly IR, reflected from such laminate can be readily distinguishably different from the spectrum of that radiation reflected from a single layer of the material of either of its layers.

If the stream is a continuous strip of laminate advancing on a laminating machine, for example a polymer coating machine coating a polymer layer onto a substrate, it is possible to detect any variation in composition of the advancing polymer layer and to correct the coating process accordingly.

Alternatively, it is possible to separate-out objects,

e.g. waste objects, of a predetermined composition from a stream of matter, e.g. waste matter, which can be relatively wide compared with a sequential stream, so that a relatively high rate of separation can be achieved.

Typically, there could be a transverse row of some 25 to 50 detection zones for a stream 1m. wide. A central detection system can be applied to "serve" all 25 to 50 detection zones if there is sufficient IR intensity across the width of the stream from a single or multiple IR source or even if there is an infrared source at each detection point. Optical fibres may lead the reflected IR from the detection points to this central detection system. However, a system of IR reflectors is preferred to optical fibres, since a reflector system is less expensive, allows operation at higher IR intensity levels (since it involves lower IR signal losses) and is less demanding of well-defined focal depths. If the stream moves at some 2.5 m/sec. and the system is capable of 100 to 160 scans across the stream each second, then detections can be made at a spacing of some 2.5 to 1.5cm along the stream. When each scan is divided into 25 to 50 detection zones, detections can be made in a grid of from 1.5 x 2.0cm. to 2.5 x 4.0cm. The transverse scanning of the moving stream makes it possible to construct a two-dimensional simulation which can be analysed using image processing. In this way it is possible to detect:

matter composition, e.g. thickness, and position in the stream

shape and size of composition variation

several composition variations substantially simultaneously.

The detection data processing system will determine wanted/unwanted composition at each detection zone.

For food quality control, e.g. fat content and maturing of fish and the maturing of meat, the apparatus measures the quality of foodstuff by monitoring the absorption spectrum in the IR range.

Although an advantage of arranging the detection of

objects from underneath (rather than above) the waste stream is that it gives as uniform a distance from detection point to object as possible, it has disadvantages. By irradiating the waste objects on a conveyor belt with radiation from above and by utilising a reflector system to select that portion of the reflected radiation which propagates upwards, the system can be made very focusing insensitive. The alternative of the stream being in free fall is particularly advantageous in enabling the distance from detection point to object to be as uniform as possible, while avoiding many of the disadvantages of detection from underneath.

In addition to or instead of spectral sensing devices, electromagnetic sensing devices may be employed at a metal-detection station. By means of an antenna extending across the advancing stream, an alternating electromagnetic field can be set up across the stream. By providing as many eddy current detection zones (in the form of individual detection coils) across the stream as there are spectral detection zones a simultaneous metal detection can be performed at very low additional cost. Thereby, with a waste stream including polymer-coated beverage cartons, and with several air jet arrays arranged one after another it becomes possible to sort out:

beverage cartons without an aluminium barrier
beverage cartons with an aluminium barrier
other metal-containing objects.

With a more elaborate spectral analysis it also becomes possible to identify and sort out the type of polymer in a plastics object. The system could hence be applied to sorting into separate fractions the various plastics types occurring.

By employing one-and-the-same detection station for at least two streams simultaneously, the cost of inspection can be reduced compared with a case where the streams have respective detection stations.

In order that the invention may be clearly and completely disclosed, reference will now be made, by way of example, to

the accompanying drawings, in which:-

Figure 1 illustrates diagrammatically, in perspective view from above, a system for automatic sorting of waste objects of differing compositions,

Figure 2 illustrates diagrammatically, in front elevation, a modified version of the system, with two rotary polygonal mirrors in respective first angular positions,

Figure 3 is a view similar to Figure 2, but with the mirrors in second angular positions,

Figure 4 is a view similar to Figure 2 or 3, but of another modified version of the system,

Figure 5 illustrates diagrammatically, in perspective view from above, a further modified version of the system,

Figure 6 illustrates diagrammatically, in front elevation, a modification of the system,

Figure 7 is a view similar to Figure 6 of another modification of the system,

Figure 8 is a view similar to Figure 1 of a yet further modified version of the system,

Figure 9 shows a diagrammatic vertical section through a yet still further modified version of the system,

Figure 10 shows a diagrammatic horizontal section taken on the line X-X of Figure 9, and

Figure 11 shows a detail of Figure 9.

The present system utilizes principles of the system of WO-A-96/06689 and reference should be made to the latter for any necessary clarification of the present description with reference to the present drawings.

Referring to Figure 1, a detection station 2 including a vertically downwardly directed video camera 4 and a detection unit 6 identical to one of the two units 6 to be described with reference to Figures 2 and 3 has a stream of waste matter, including objects 14 such as containers, advanced therethrough on a substantially horizontal conveyor belt 8 to a transverse array of air jet nozzles 10. The rectangular picture area of the camera is indicated at 12 and spans the whole width of the belt 8 and thus of the stream of waste. The data from the camera 4 is used to identify the positions

of individual objects in the waste stream (in the sense of approximately the region that the object occupies in the stream of waste). The unit 6 scans the stream of waste along a rectilinear path P also extending the whole width of the belt 8 and thus of the waste stream, the path P being perpendicular to the longitudinal direction D of the belt 8, i.e. to the feed direction of the waste stream. By infrared spectrum analysis, the unit 6 detects the composition of at least some of the objects 14 in the waste stream. The data from the camera 4 and the unit 6 are used to control a controller 16 for solenoid valves (not shown) which control the supply of compressed air to the respective nozzles 10. In this relatively simple system, the composition and/or colour of each object is/are detected by the unit 6, whilst the video camera is used to monitor the scanned region and its data output employed automatically to detect the positions of the objects and to correct the data relating to those objects as received from detectors 21 in the unit 6. The belt 8 may be 0.5m. wide and the camera 4 and the unit 6 be active over the whole width of the belt.

Referring to Figures 2 and 3, the units 6 are arranged side-by-side above the conveyor belt 8 which, in this version, may be 1.0m. wide. Each unit includes a housing 18, of which the front cover has been removed from the left-hand unit in Figures 2 and 3. Each housing 18 contains a mounting bracket 20. The detection station 2 differs from the detection station 131 of the version of Figure 11 of WO-A-96/06689 chiefly in that there are two units 6 disposed side-by-side and that, in each unit 6, the cylindrical, polygonal mirror 108 of that Figure 11 has been re-orientated such that its axis of rotation R now extends in the feed direction D (such mirror being referenced 19 in the present drawings). Not only does this change simplify the path of transmission of the varied IR radiation from the stream of matter to the filter/detector combinations 21, but the loss of IR intensity produced by such a relatively long path as in that Figure 11 can be minimised. The filters/detectors 21 are parts of an optical detection device 22 which includes a beam splitter 24

and is mounted on the bracket 20. Also mounted on the bracket 20 is a microprocessor 26 which receives the data output from the filter/detectors 21 (and from the camera 4 if provided) and data as to the angular position of the rotating polygonal mirror 19 and controls accordingly the controller 16. The polygonal mirrors 19 rotate in the senses of the arrows A and the starting path of the diffusely reflected IR via each mirror 19 to its associated beam splitter 24 at the commencement of a scan is indicated by the dot-dash line S and its finishing path at the end of the scan is indicated by the dot-dash line F. One unit 6, or a row of at least two units 6 side-by-side, is/are applicable not only to material being advanced by a conveyor belt, but also to material advancing down a slide or to material advancing in free fall. With the three filter/detectors 21 shown, the unit 6 is able to perform simultaneous analysis of three wavelengths of electromagnetic radiation. At least three wavelengths and thus a corresponding number of filter/detectors are chosen if IR is used as the detection medium, in order to detect composition of the matter, or two wavelengths and thus two filter/detectors in the event that visible light is chosen as the detection medium, in order to determine the colour of the matter. The polygonal mirror gives relatively high scanning speed with relatively moderate rotational speed of the mirror. The radiation reflected from the matter over the scanning width is converging.

The spacing between the or each polygonal mirror and the stream of matter is kept as small as practical, in order to maintain high resolution and intensity of reflected radiation with relatively low illumination intensity.

Compared with, for example, the detection system of Figure 11 of WO-A-96/06689, the system of the present Figures 2 and 3 allows a higher resolution and a somewhat better signal-to-noise ratio to be obtained. Moreover, the distance which the reflected radiation has to travel from the matter to reach the filter/detectors 21 can be relatively reduced by up to one half, so reducing light transmission losses, which can be quite significant if the reflected radiation has to travel

through a polluted, e.g. dusty, atmosphere and/or indirectly via an intermediate mirror.

Parallactic and shadowing effects can be kept within tolerable limits for objects less than, e.g. 200mm., tall if the transverse angle of reflection can be kept within some 30° from the vertical. During each scan, the reflection point on the polygonal mirror will move over the surface of the mirror in the direction of scan, which somewhat reduces the angle of reflection towards the end of the scan.

With an hexagonal mirror, for example, a new scan will start upon 60° rotation of the mirror. However, each scan requires somewhat less than half of that 60° rotation to be completed, and thus an interval probably longer than the actual scan period exists in which, for instance, some detector calibration can be undertaken. However, the spectral analysis and two-dimensional simulation of the stream are largely carried out in parallel with the data acquisition, which is practically continuous.

An average minimum object height of, for example, 3cm. may be pre-set as a reference to correct for some of the parallactic error.

It is advantageous to have a slight overlap of the inner ends of the widths scanned by the two units 6, in order to avoid inadvertent failure to detect objects or parts of objects in the border zone. Each unit 6 operates independently of the other, even to the extent of controlling its own array of air jet nozzles (not shown).

In an alternative embodiment the widths scanned by the two mirrors 19 may overlap fully, the mirrors 19 being displaced relatively further from the advancing matter than as shown in Figures 2 and 3. If the mirrors 19 are placed substantially directly above the respective edges of the stream of matter as shown in Figure 4, the parallactic and shadowing effects can be cancelled out during the processing of the data. Naturally, a higher intensity of illumination of the matter will be required.

Referring to Figure 4, the axes A of the mirrors 19 are directly above and parallel to the respective edges 8a of the

belt 8 and are disposed at the same level as each other at a known distance d above the belt 8 which is of a known width W. An object 14a is shown disposed on the belt 8 having top, left-hand corner TLa, top right-hand corner TRa, bottom left-hand corner BLa, and bottom right-hand corner BRa. It will be understood that position (BLa-BRa) relative to the belt, object height h and object width w can be determined once angles α TRa and α BLa relative to the left-hand axis A and α TLa and α BRa relative to the right-hand axis A are known. These angles refer to the points TRa to BRa, respectively, at which sudden variations of wavelength and/or intensity of the diffusely reflected IR received by the left-hand or right-hand mirror take place, so that these angles can be determined by the microprocessor 26 from the detection data received thereby.

If there is, for one of the mirrors 19, a sudden variation of the diffusely reflected IR at the point TLa (for the left-hand mirror 19) or TRa (for the right-hand mirror 19), for example because the top surface (between TRa and TLa) is more intensely irradiated with IR than the side surface (between TLa and BLa or between TRa and BRa), then the other unit 6 can be dispensed with, because the one unit 6 on its own can measure position and both h and w.

In still another embodiment, using one polygonal mirror 19, it is possible to have multiple detectors for each wavelength in the device 22. In this way, either, as will be described with reference to Figure 7 the optical resolution can be improved, thereby assisting detection of very small objects such as might be present in streams of fragmented matter, or the same optical resolution of a scanning module 6 could be maintained whilst increasing the spacing between the mirror 19 and the matter.

Referring to Figure 5, waste matter advanced by a feed conveyor belt 30 inclined downwardly at a slight angle β to the vertical drops onto a dome 31 surmounting a conical or elliptical deflector 32 so that the waste becomes distributed at a substantially constant radius about a vertical axis V of the deflector 32. The dome 31 is provided with outwardly

diverging guide fins 33 so as to spread the waste matter more evenly around the conical or elliptical deflector 32. A higher sorting capacity can be achieved by the provision of the fins 33, since the tendency for the waste matter to be concentrated at the middle of the front of the circumference of the deflector 32 is reduced, in other words more waste matter can be sorted because the waste matter can be denser in the stream passing over the deflector 32 without portions of the waste matter overlapping each other. Below the deflector is a housing 34 having its front wall 34a substantially coaxial with the axis V and formed with a horizontal slot 36 also co-axial with the axis V and at the same level as a cylindrical, rotary, polygonal mirror 19 co-axial with and rotating about the axis V, and as an optical detection device 22. The housing 34 also contains lamps 38 for illuminating the matter falling freely past the slot 36. Radiation reflected from the falling matter is then reflected to the mirror 19, which scans the falling matter at a substantially constant distance from the matter in the horizontal plane of the slot 36. Arranged below the housing 34 are a number of air jet nozzle arrays 40 arranged parallelly with the slot 36 at substantially the same radius from the axis V. Arranged radially outwardly beyond the falling matter are a number of collector shields 42 spaced radially outwardly from each other. The greater its radius from the axis V, the higher the shield 42 extends.

In use, the composition of the matter falling past the slot 36 and/or the relative position of objects 14 falling past that slot is/are detected and the nozzles of the arrays 40 activated accordingly, to sort the objects 14 into the spaces among the shields 42 and at the outside of the outermost shield 42, the remainder of the matter simply continuing to fall vertically to the inside of the innermost shield 42.

The downward inclination of the belt 30 is provided to promote downward acceleration of the matter as it leaves the belt. This downward acceleration increases vertical speed of the matter and thereby the capacity of the apparatus. It may

also be advantageous to have a relatively large radius of the front end roller 44 of the belt conveyor to promote such downward acceleration and to reduce rolling of the objects 14.

Use of the finned dome 31 and the deflector 32 promotes distribution of matter into a freely falling distribution co-axial with the axis V. This has the advantage that, because the mirror 19 is also co-axial with the axis V, no significant parallactic error arises. Instead of the lamps 38 being mounted within the housing 34, they may be mounted exteriorly thereof.

In the version of Figure 5, the detecting means, the illuminating means and the ejecting means can be assembled as a single unit. It is believed that ejection of more than one fraction of the matter is feasible at different levels as the matter is falling. However, monitoring by camera may be required to give more precise ejection, especially if more than two desired fractions are to be ejected.

The system of Figure 5 has a particular advantage in that it can occupy less floor area than an equivalent horizontal system.

Referring to Figure 6, although this modification is illustrated in relation to matter on a conveyor belt 8, it is also applicable to matter advancing down a slide or to matter in free fall. A polygonal mirror 19 is again shown scanning the matter; however, in this case the mirror 19 is not only receiving reflected light from the matter on the belt 8 and reflecting it to the optical detection device 22, but it is also receiving the matter-illuminating electromagnetic radiation, for example visible light, from two collimators 46 and reflecting the collimated light beams B onto a transversely scanning spot on the matter. This alternative to having stationary light sources has the advantage of greatly reducing the illumination energy requirements for the same reflected radiation intensity level at the device 22. Use of the hexagonal mirror (possibly via another mirror between it and the advancing matter) for reflection of both the illuminating beams and the return beams has the advantage of

providing totally reliable synchronisation thereof. Alternatively, it would be possible to use two separate polygonal mirrors, one for the illuminating beams and one for the return beams, on either the same rotary body, or on differing rotary bodies but then, in the latter case, some form of synchronising arrangement would additionally be required. Whatever the light sources used, be they the collimators 46 or otherwise, direct radiation reflection onto the splitters in the device 22 may present the problem of saturating the sensitivity of the detectors, in which case such direct reflection must be avoided. This can be achieved by offsetting the light sources relative to the beam splitters, as indicated in Figure 6. If desired, the separate collimators 46 could be replaced by a ring-shaped collimator centred around the radiation inlet of the device 22.

In the modification shown in Figure 7 (again applicable to matter on the belt 8 or advancing down a slide or in free fall), the unit 6 contains, in addition to the mirror 19 and the microprocessor 26 (not shown), two devices 22 side-by-side with each other and arranged to receive diffusely reflected radiation simultaneously from respective detection zones $Z_1$ and $Z_2$ located adjacent each other along the path P, so that there are there are two filter/detectors 21 (not seen) for the or each electromagnetic radiation wavelength detected. As scanning proceeds, different pairs of detection zones along the path P are inspected. In a variation (not illustrated) of that modification, the two devices 22 are replaced by a single device 22 containing double filter/detectors 21.

Referring to Figure 8, in this version a module 50 emits a transversely scanning beam B of electromagnetic radiation visible to a camera 52 directed obliquely to the direction D and disposed in a central vertical plane of the belt 8. The beam B irradiates a path P' which extends across the belt 8 and generally up, over and down each object 14 being advanced by the belt 8 at the detection station 2. The camera 52 can thereby be employed to detect the general profile of each object, for example as to whether it is of rectangular cross-

section, as is the gable-topped carton 14a, of substantially constant circular cross-section, as is the can 14b, or of varying circular cross-section, as is the bottle 14c. The camera 52 also detects the positions of the objects 14. It is thus possible to sort these objects from one another. In addition, if the module 50 has the same capability as does the module 6, with the modification according to Figure 6, of determining the compositions of the objects 14 from diffusely reflected electromagnetic radiation of the beam B, the compositions of the objects, as well as their general profiles and positions, can be determined. This version is, of course, applicable not only to material being advanced by the belt 8 but also to material advancing down a slide or in free fall.

Referring to Figures 9 to 11 this version differs from that of Figure 5 chiefly in that the radiation, which comprises visible light L, passes through the matter 14 to be inspected. Thus the light source 60 is disposed outside the housing 34 which contains the rotary polygonal mirror 19 and the detection device 22. The light source 60 contains two horizontal fluorescent tubes 62 which each extend over the whole width of the stream of matter 14 and are surrounded by a horizontal casing 64 except for a horizontal slot-form exit 66 for the light. The tubes 62 are arranged respectively above and below the exit 66, and the internal surface of the casing 64 is reflective of visible light. Thus, the light L leaving the exit 66 has been collimated to some extent. The use of relatively collimated light substantially normal to the stream of matter 14 should facilitate reliable analysis. The light passes through the slot 36 to a Fresnel lens 68 which extends over the width of the stream of matter 14 and, at least in a horizontal plane, causes the light L to converge to an inner wall 70 formed with an inner aperture 71 in the form of a horizontal slot, whence the light L continues to converge towards the polygonal mirror 19. The arrangement is such that the portions 64a of the casing 64 prevent the light L from travelling directly from the fluorescent tubes 62 to the detection device 22. The matter

14 is particularly advantageously in the form of crushed bottles of differing colours of relatively transparent plastics. The bottles leaving the conveyor belt 30 strike a short guide 72 which discourages spinning of the crushed bottles about their own axes; this reduces the production of false data from the device 22. Depending upon the colours of plastics identified from the inspection of the bottles, the air jet nozzle array(s) 40 sort(s) the matter 14 into one or more desired colour fractions 72 and a remaining fraction 74.

In operation, three wavelengths of the radiation, i.e. three colours, are analysed, all in the spectrum (400 to 700mn) of visible light.

It is believed that having at least two fluorescent tubes 62 and using only diffusely reflected light for penetration of the objects, with mixing of the light from the plurality of tubes 62, reduces the effect of aging of the tubes 62.

The light source 60 may deteriorate in various ways; for example, the tubes 62 may change their light emission through aging (as already mentioned above), or through extraneous material interfering with the emitted light. To counteract such deterioration, an optical analysis system of the device 22 is continually calibrated and corrected by analysing every detection zone where no matter 14 is present. In this way, local variations along the length of the light source can be corrected for and spectral shifts in start-up periods and aging of the tubes 62 can be compensated for. The reading obtained from the last detection zone across the detection section is compared with the detections made when the light is transmitted through a clear, transparent object. Any changes in the light intensities received are automatically employed to adjust the intensity reference values of the optical analysis system.

The front wall 34a helps to prevent the matter 14 from fouling the lens 68, whilst the inner wall 70 suppresses stray reflections and multiple images.

It will be noted that the matter 14 in free fall at the detection level in Figures 5 and 9 is travelling more vertically than horizontally. This has the advantage that a

relatively small floor area can be occupied by the apparatus, which is a feature of particular advantage in recycling plants or on lorries where plenty of vertical space, but not of horizontal space, is usually available. Moreover, this is the preferred arrangement when the apparatus is to eject by means of nozzle arrays 40 a plurality of fractions of the matter 14 on the basis of one scan of the matter.

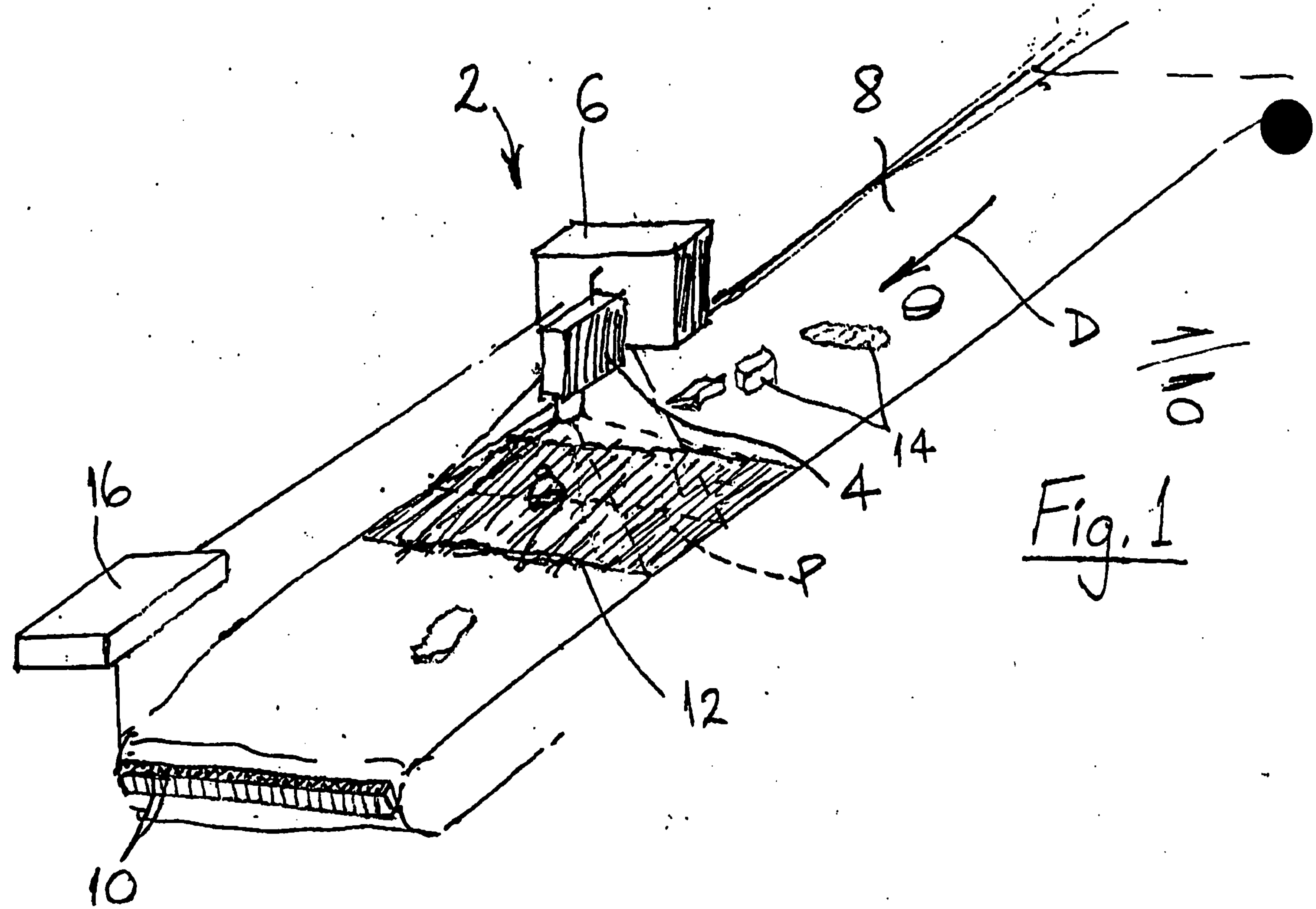



Fig. 1

20/09 '99 MON 17:20 FAX 01462 670823 ANTHONY BURROWS 039
20-09-99 17:06 01462 670823

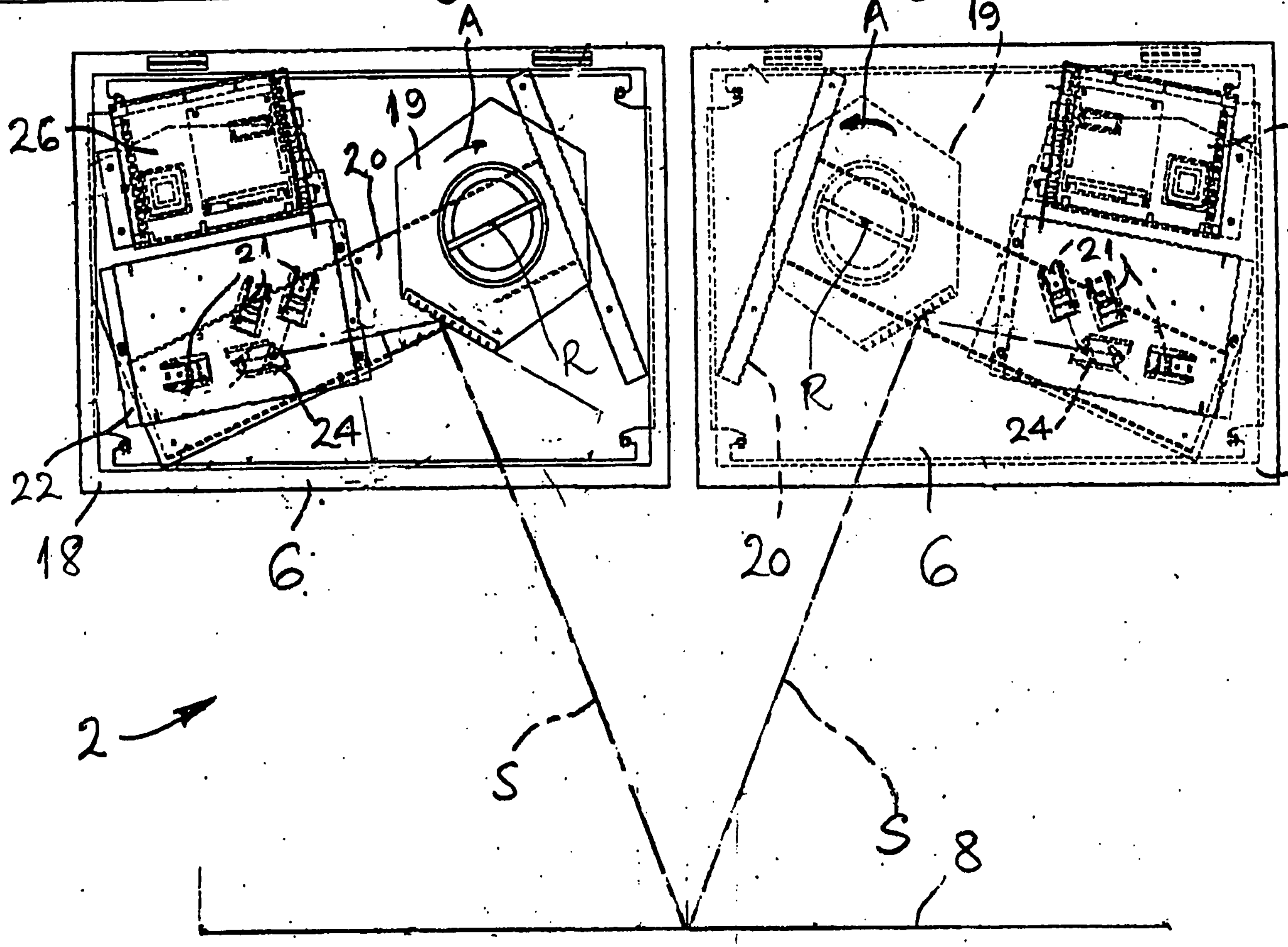



Fig. 2

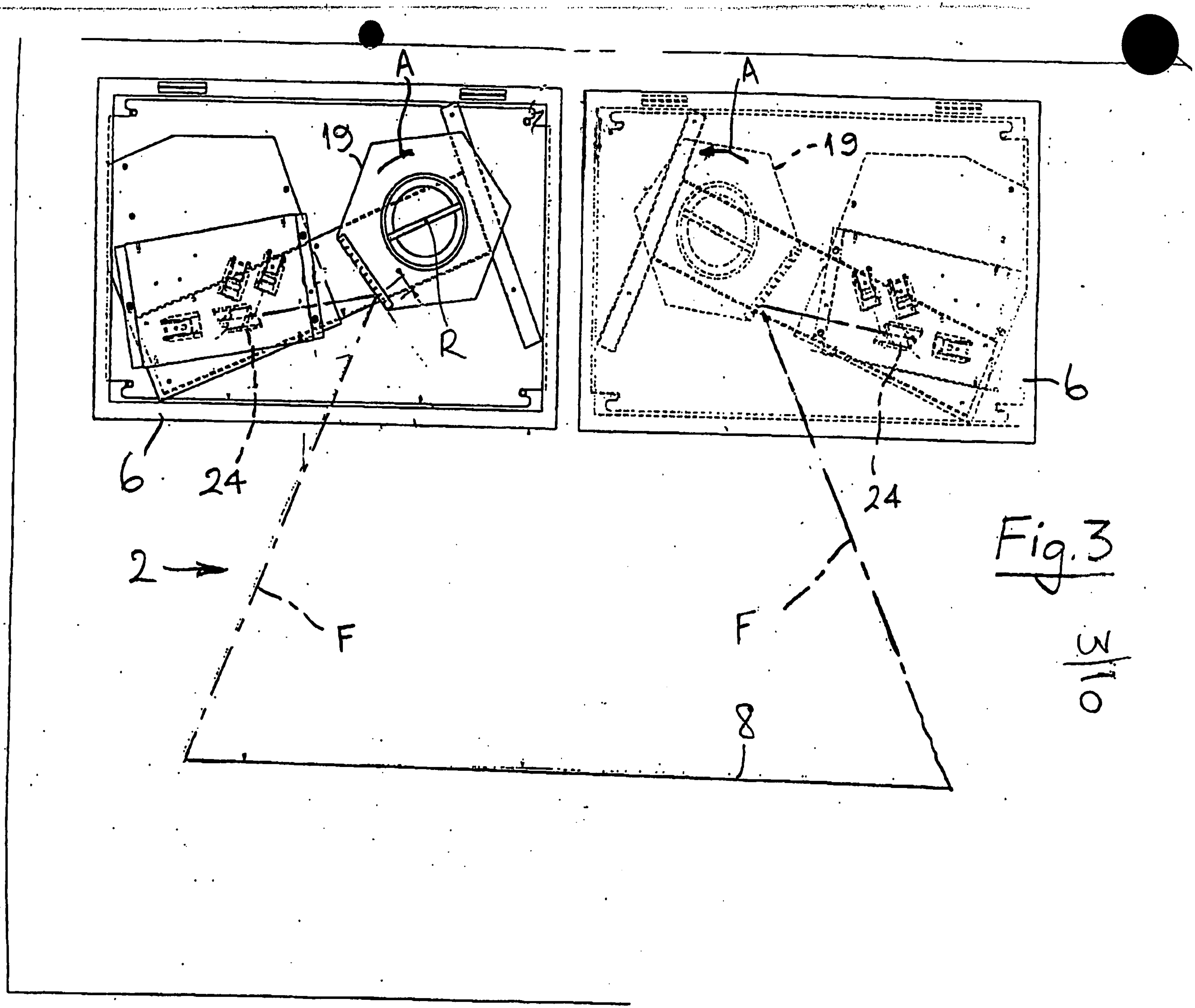
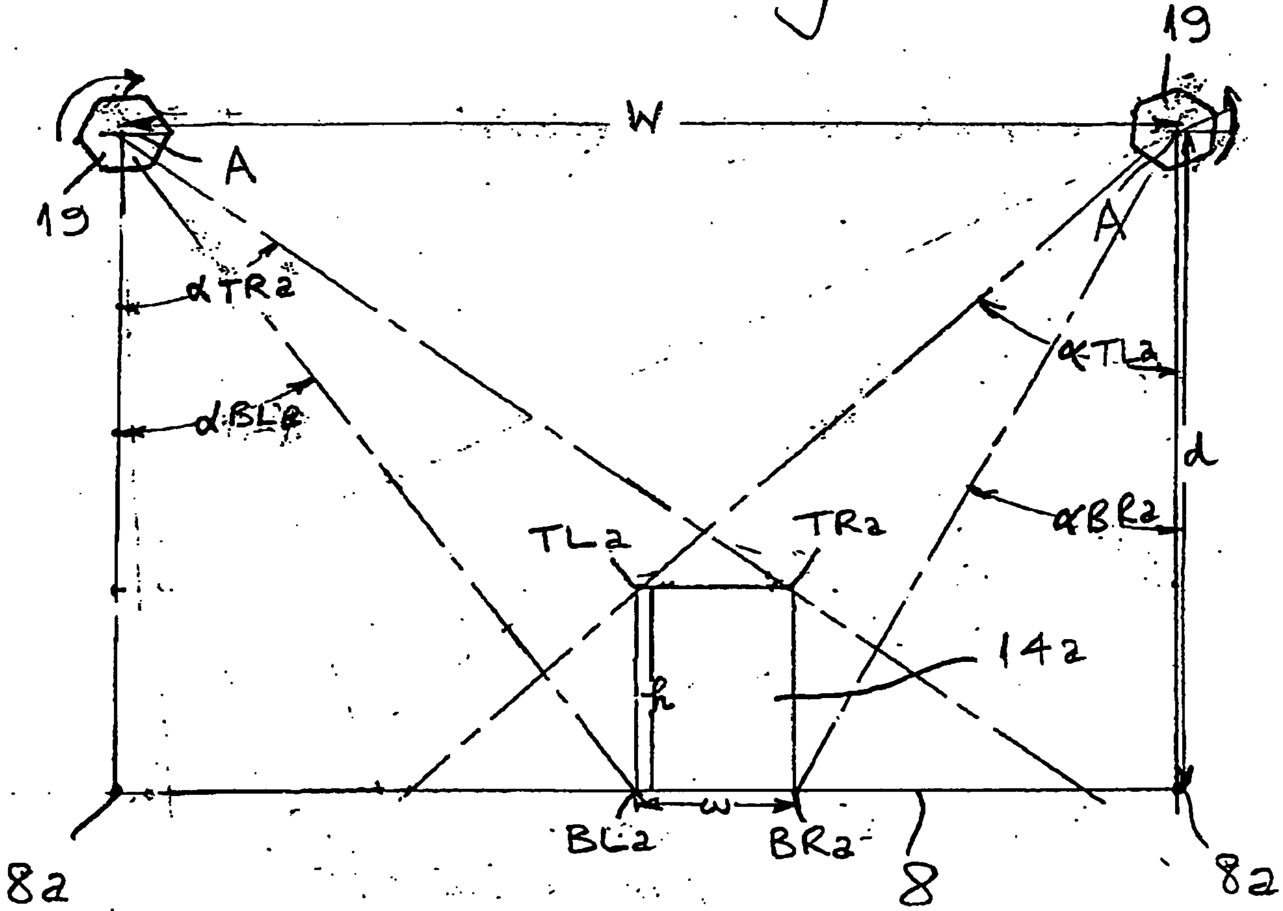



Fig. 3

# Fig. 4



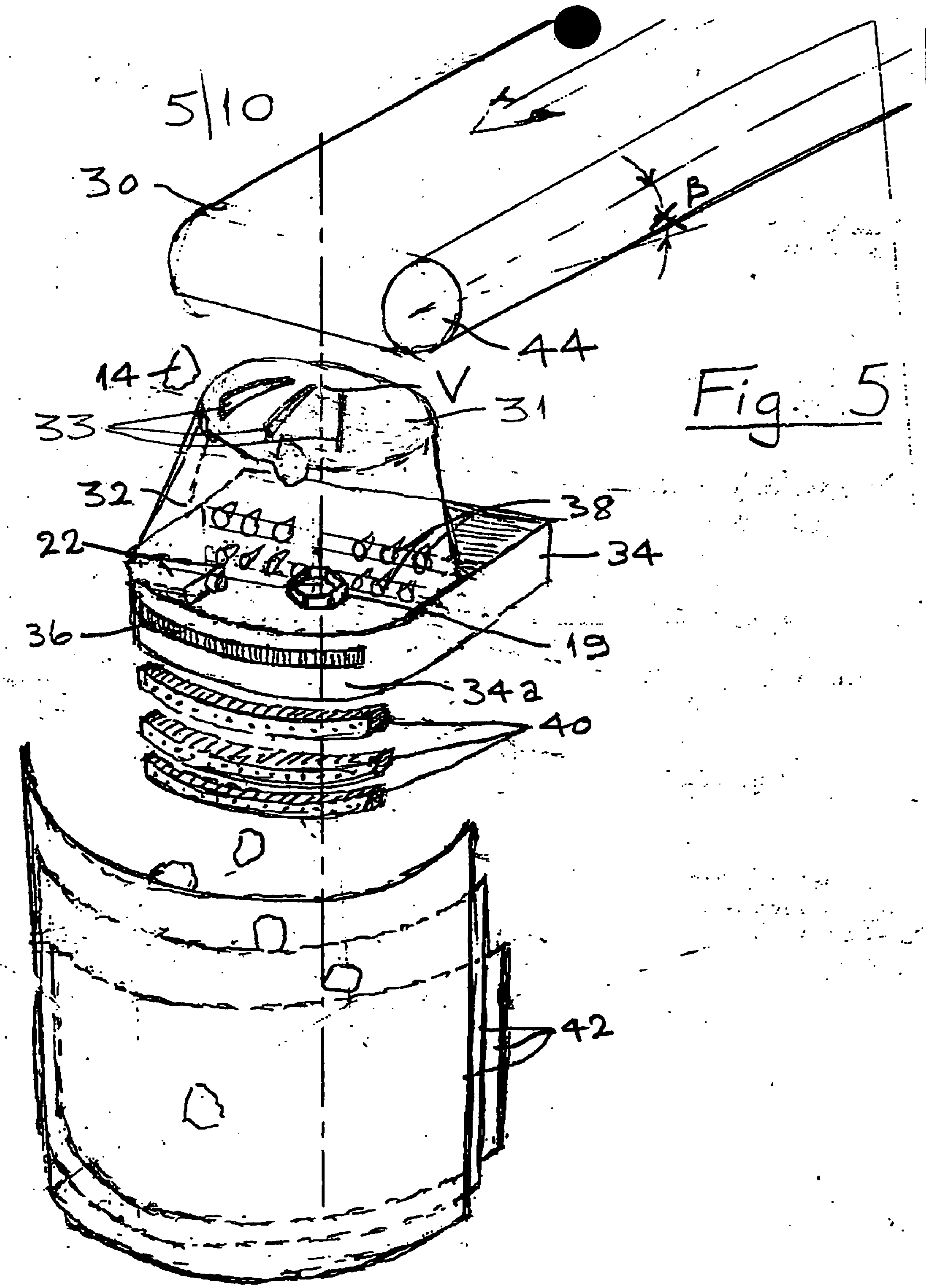
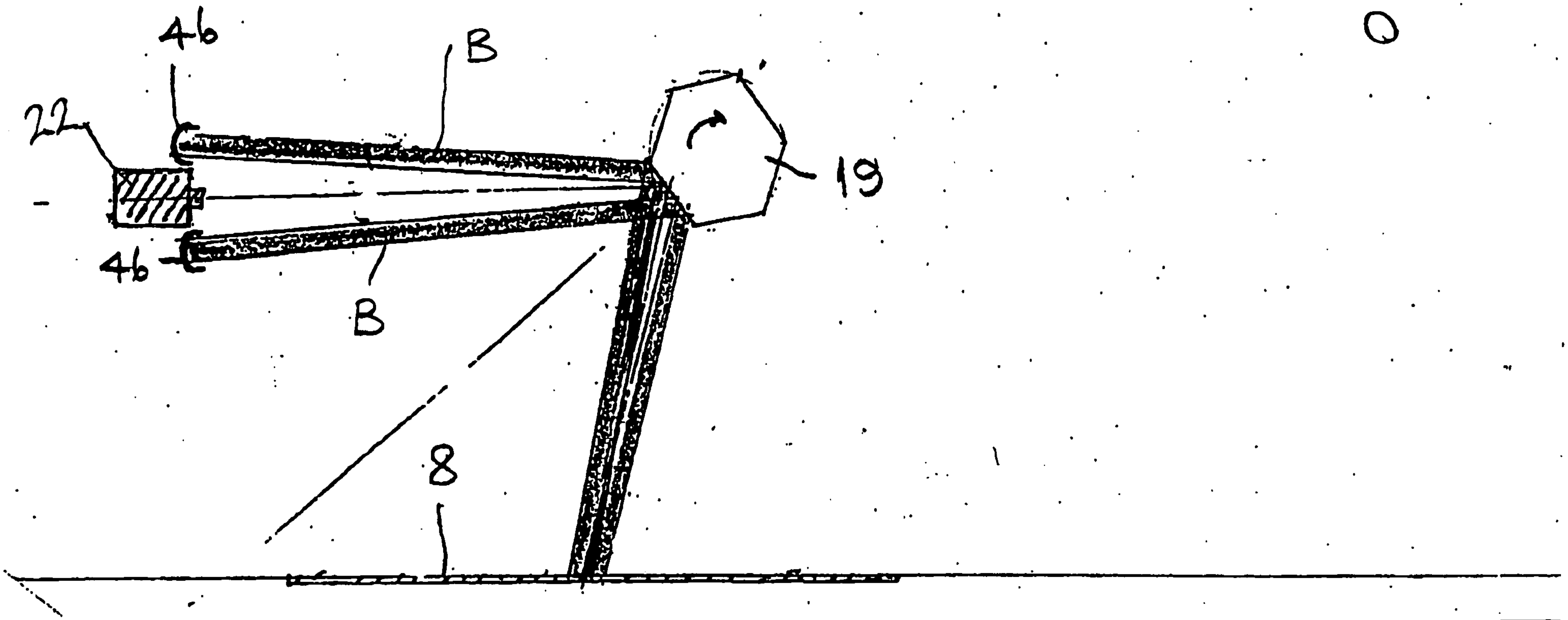



Fig. 5

Fig. 6




20/09 '99 MON 17:21 FAX 01462 670323 ANTHONY BURROWS 044

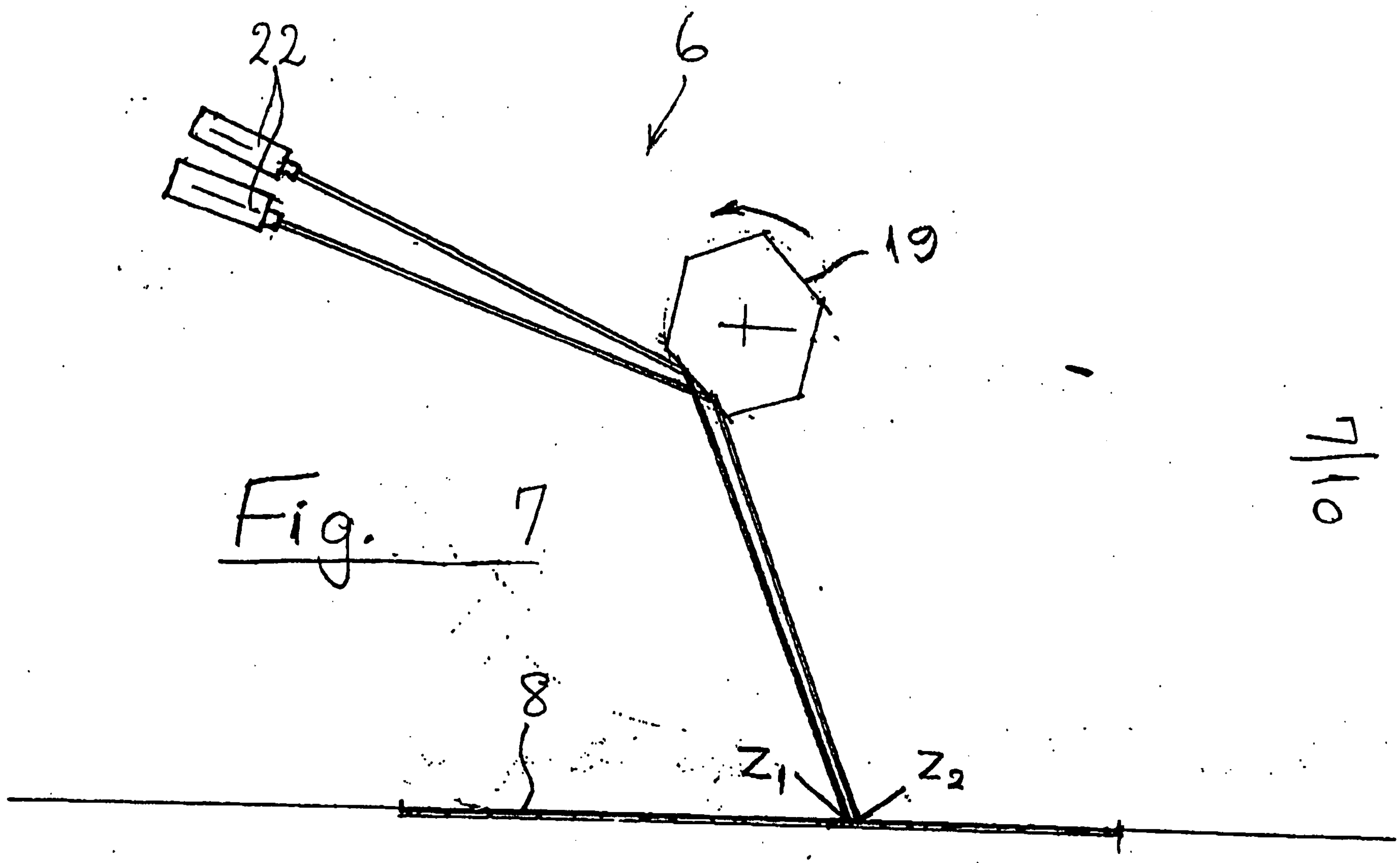



Fig. 7

20/09 '99 MON 17:22 FAX 01462 570823 ANTHONY BURROWS ☑045

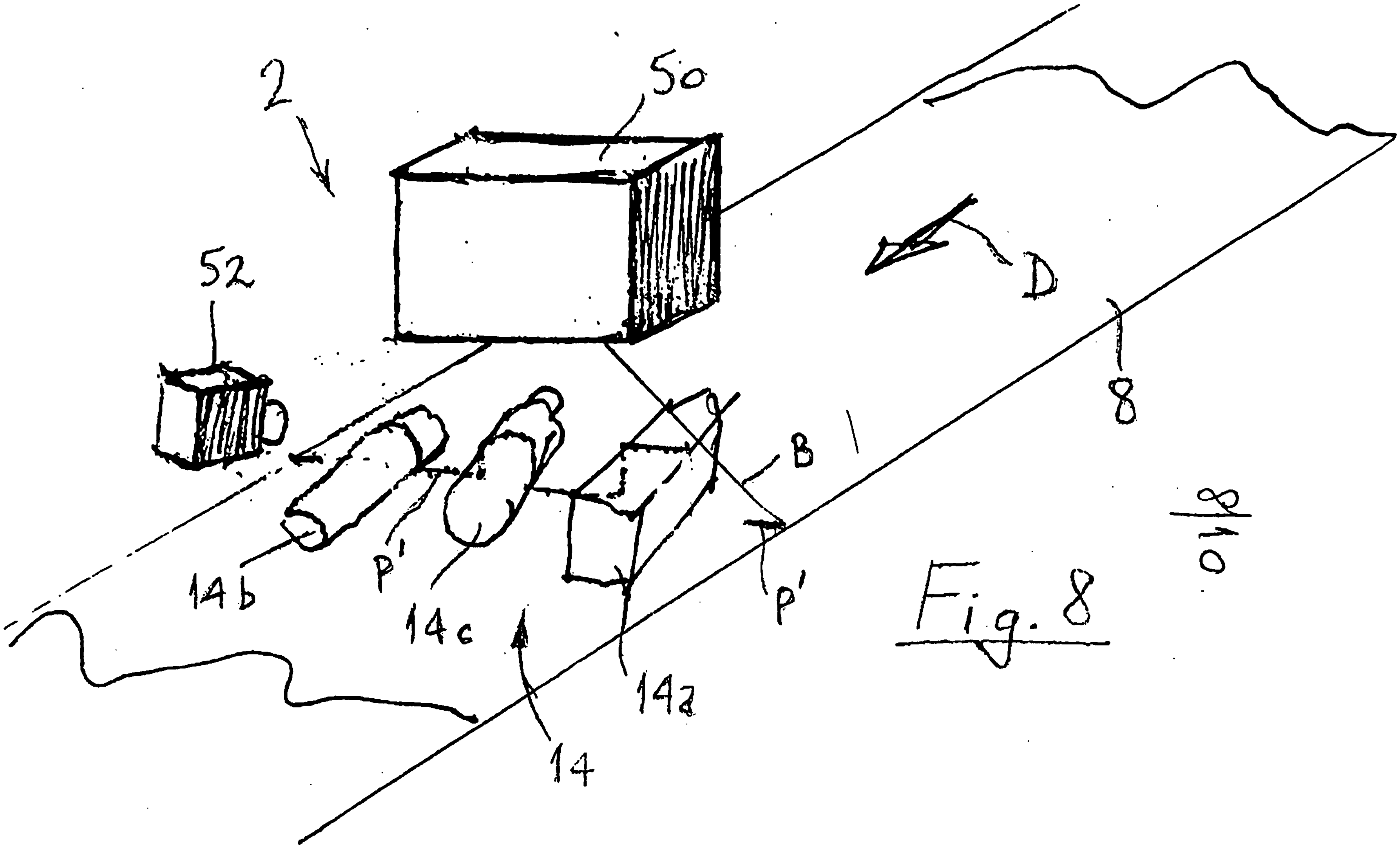



Fig. 8

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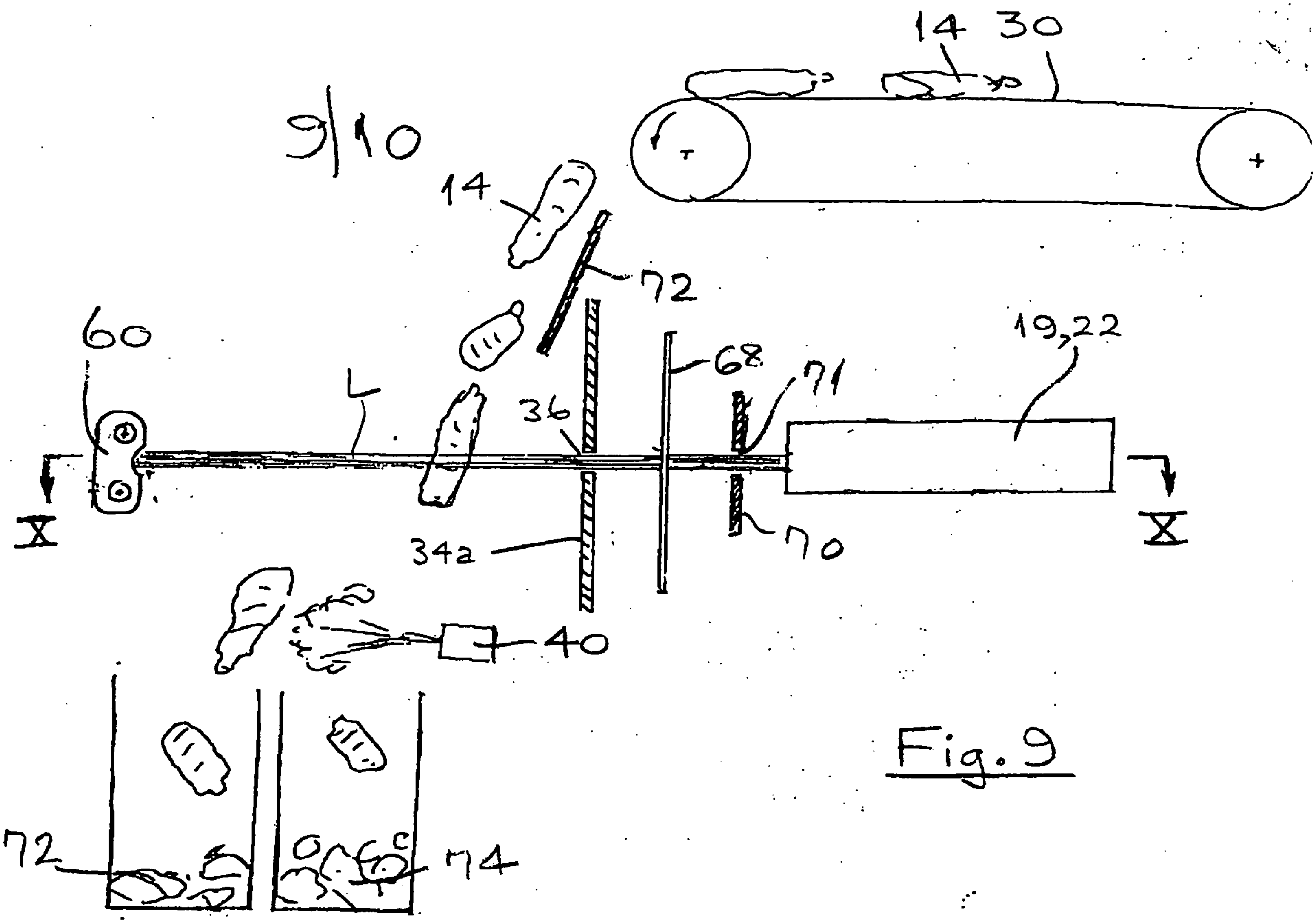
14 30
14
72
60
L
36
68
71
19,22
X
X
34a
70
40
72
74

Fig. 9

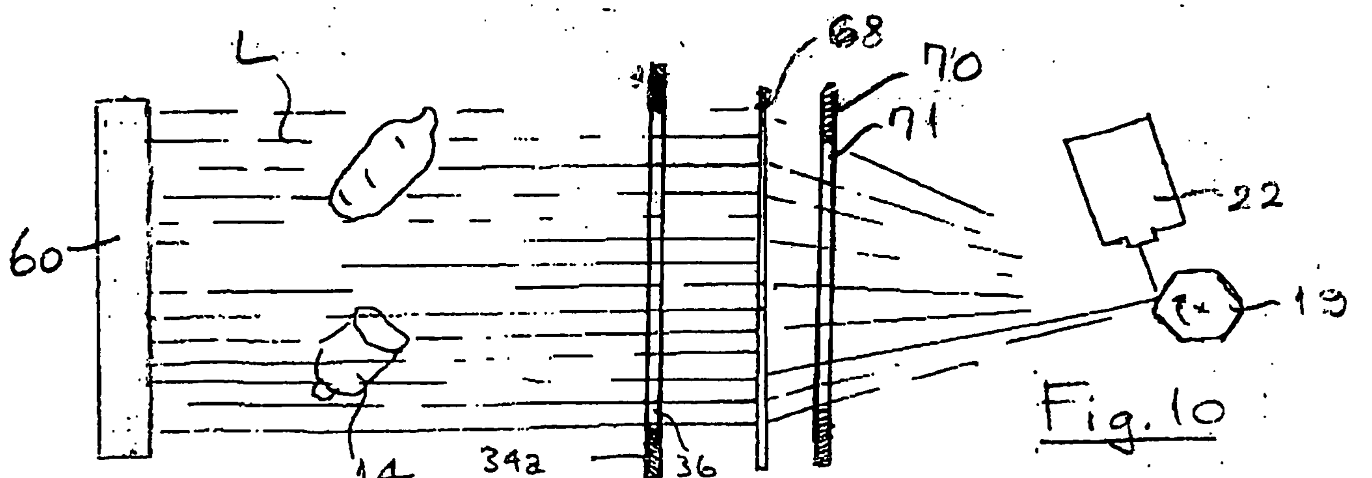
L
68
70
71
60
22
19
14
34a
36

Fig. 10

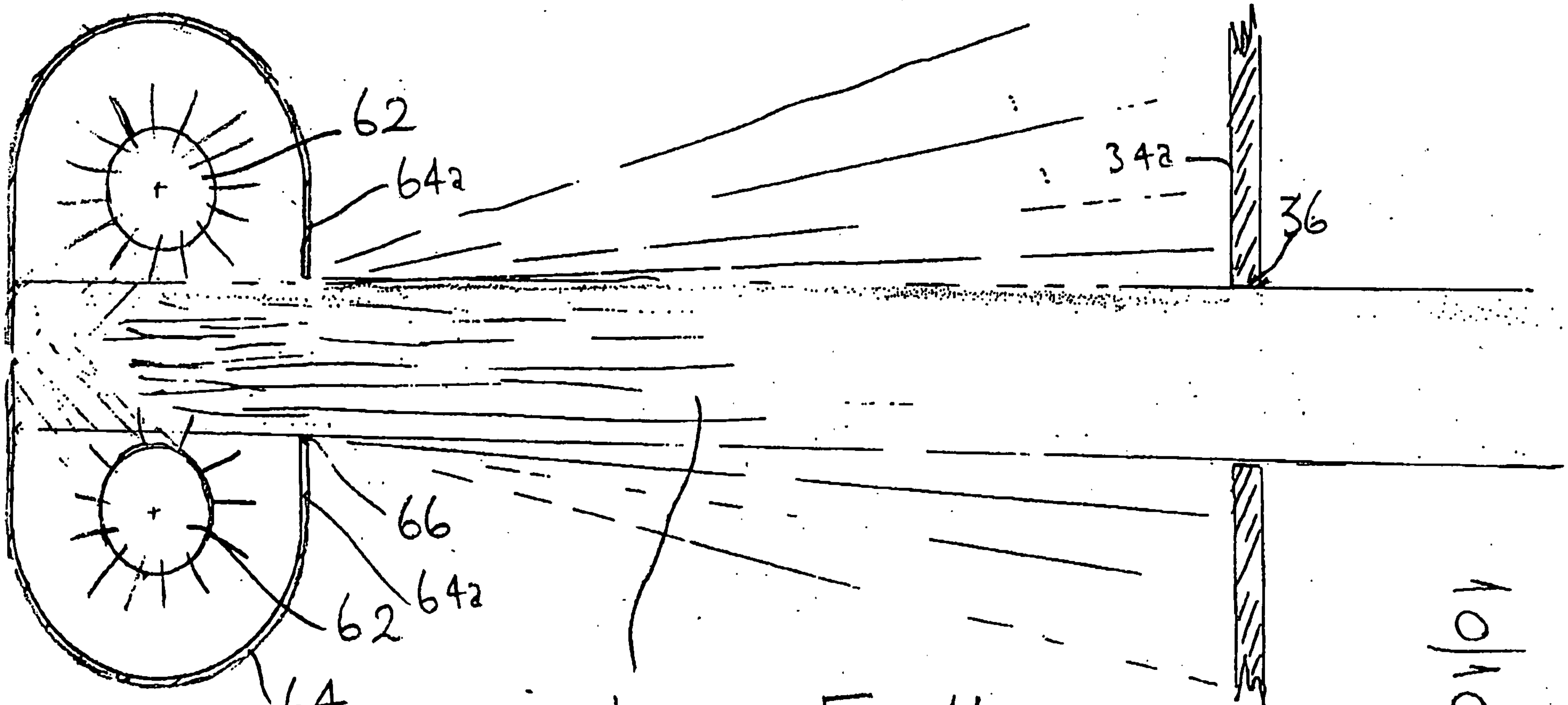


Fig. 11